An eddy-resolving ocean reanalysis using the 1/12° global HYbrid Coordinate Ocean Model (HYCOM) and the Navy Coupled Ocean Data Assimilation (NCODA) scheme

O.M Smedstad[1], E.J. Metzger[2], R.A. Allard[2], R. Broome[1], D.S. Franklin[1] and A.J. Wallcraft[2]

[1]QinetiQ North America
[2]Naval Research Laboratory

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HYCOM/NCODA Ocean Reanalysis

- Of those ocean reanalyses performed to date, only a few have eddy-permitting resolution and none are capable of fully resolving oceanic mesoscale features (eddies and current meanders) across the globe
- This project addresses the need for a long time period eddy-resolving ocean reanalysis
- Funded by the DoD Modeling and Simulation Coordination Office (M&S CO)
- Goal to the sponsor: provide physically consistent environmental scenarios for planning, wargaming and scenarios to support the warfighter
- Numerous other applications and research opportunities

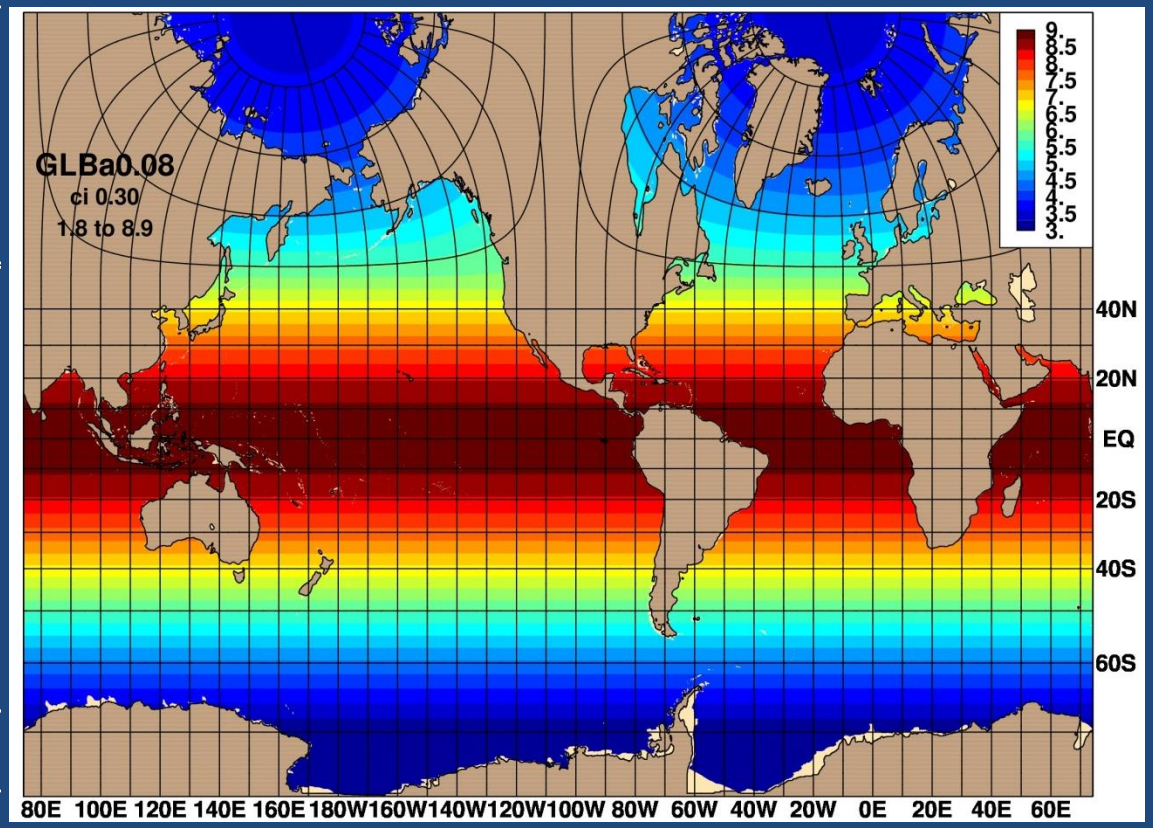
HYbrid Coordinate Ocean Model

Tri-pole latitudinal grid resolution (km)

Curvi-linear grid: north of 47°N

Mercator projection: 66°S to 47°N

Uniform cylindrical: south of 66°S



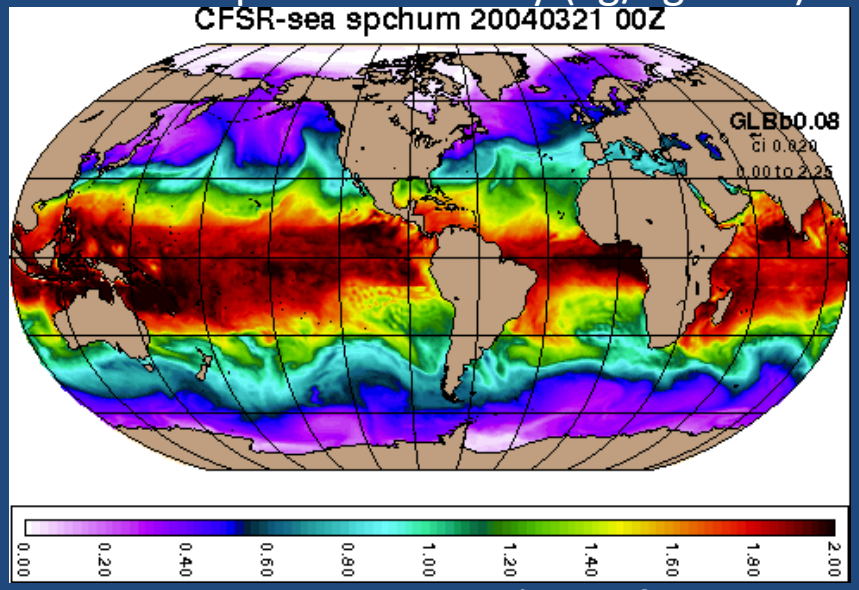
- 32 hybrid coordinate surfaces, thermobaricity, σ_2*
- K-Profile Parameterization (KPP) mixed layer model
- Monthly river runoff
- Surface salinity relaxation to U.S. Navy GDEM4 climatology
- Thermodynamic “energy loan” ice model

Atmospheric Forcing

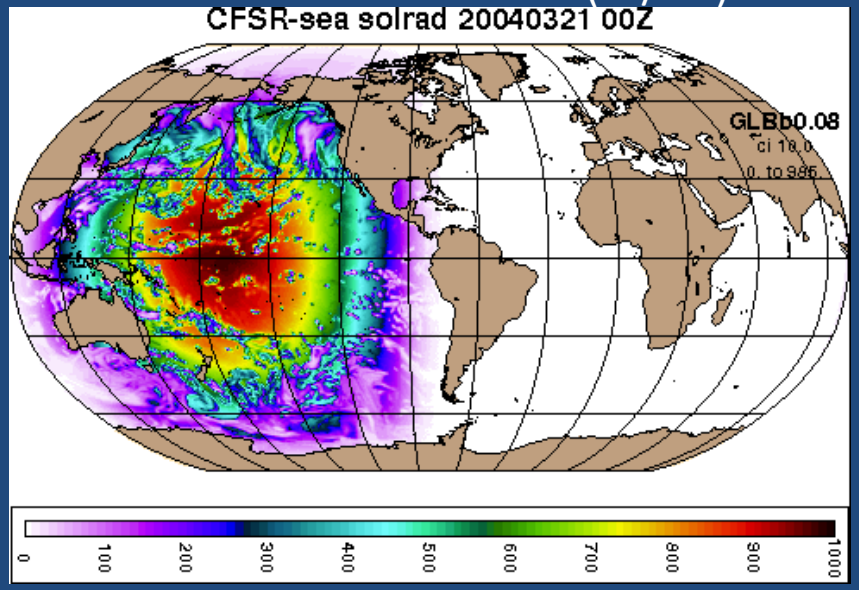
NCEP Climate Forecast System Reanalysis (CFSR)

- Time frame: 1993-2012 (altimeter period)
- Horizontal resolution: 0.3125° gaussian
- Temporal resolution: 1-hourly
- QuikSCAT scaling
- Inputs:
  - Bulk-derived wind stress
  - Wind speed
  - Radiative fluxes
  - Thermal fluxes
  - Precipitation

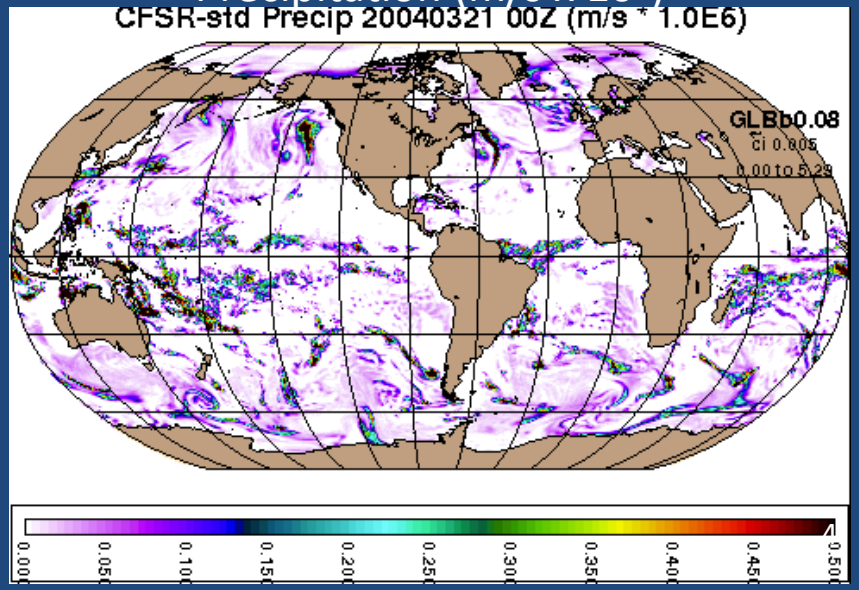
Surface Specific Humidity (kg/kg x 10^2)



Net Surface Shortwave (W/m^2)



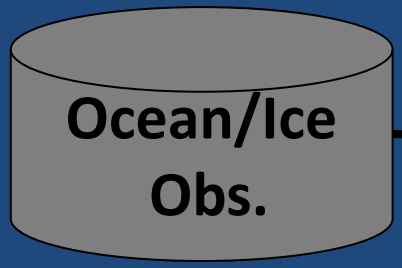
Precipitation (m/s x 10^6)



Spin-up and Reanalysis Simulations

- Spin-up 1/12° non-assimilative global HYCOM with CFSR climatology (12 model years)
- Extend climatological spin-up with 1993-2012 1-hourly CFSR forcing using 1/12° non-assimilative global HYCOM
- Extend climatological spin-up with Oct 1992-2012 1-hourly CFSR forcing using 1/12° assimilative HYCOM/NCODA
  - Begin in Oct 1992, currently in May 2000

Navy Coupled Ocean Data Assimilation (NCODA)



Sequential Incremental Analysis Update (IAU)
Analysis-Forecast-Analysis
NCODA analysis once per day that is incrementally inserted over a 6 hour window

SST: GAC/LAC MCSST, GOES, Ship, Buoy

Profiles: XBTs, CTDs, Argo floats

Buoys: Fixed and drifting

Altimeter SSH anomaly

SSM/I sea ice concentration

Ocean QC

Innovations

3DVar

Increments

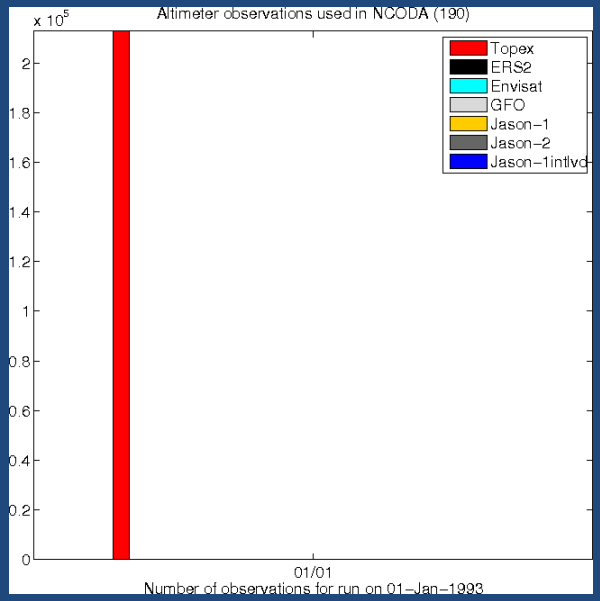
First Guess

HYCOM

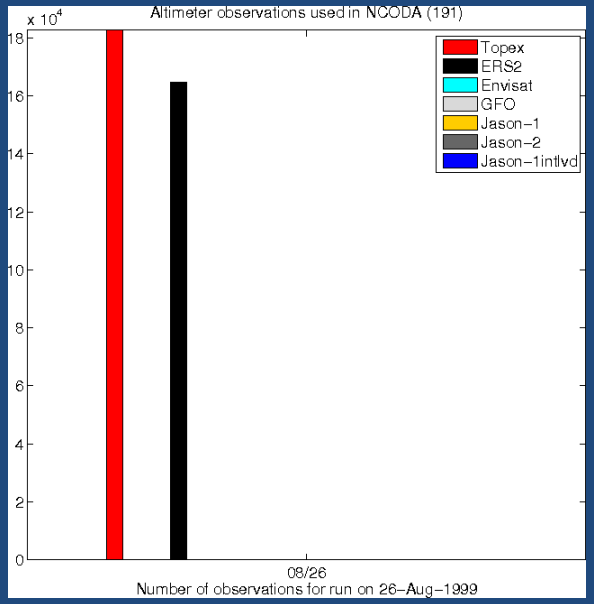
3DVar - simultaneous analysis of ice concentration and 5 ocean variables: temperature, salinity, geopotential, layer pressure, and velocity (u,v)

Altimeter Observations

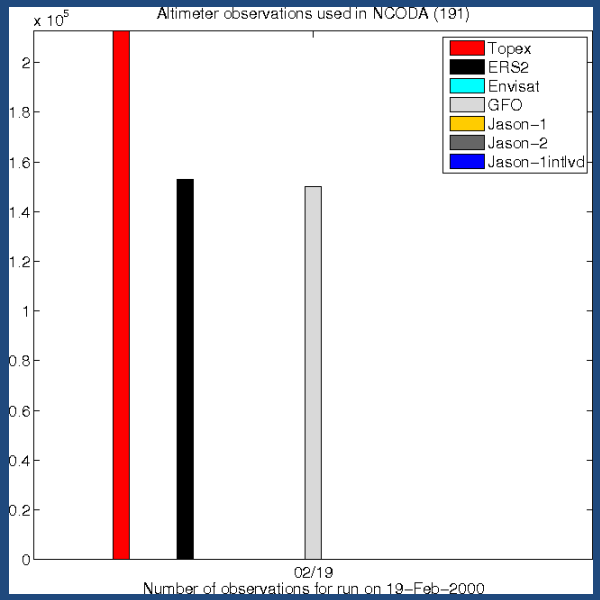
January 1, 1993



August 26, 1999

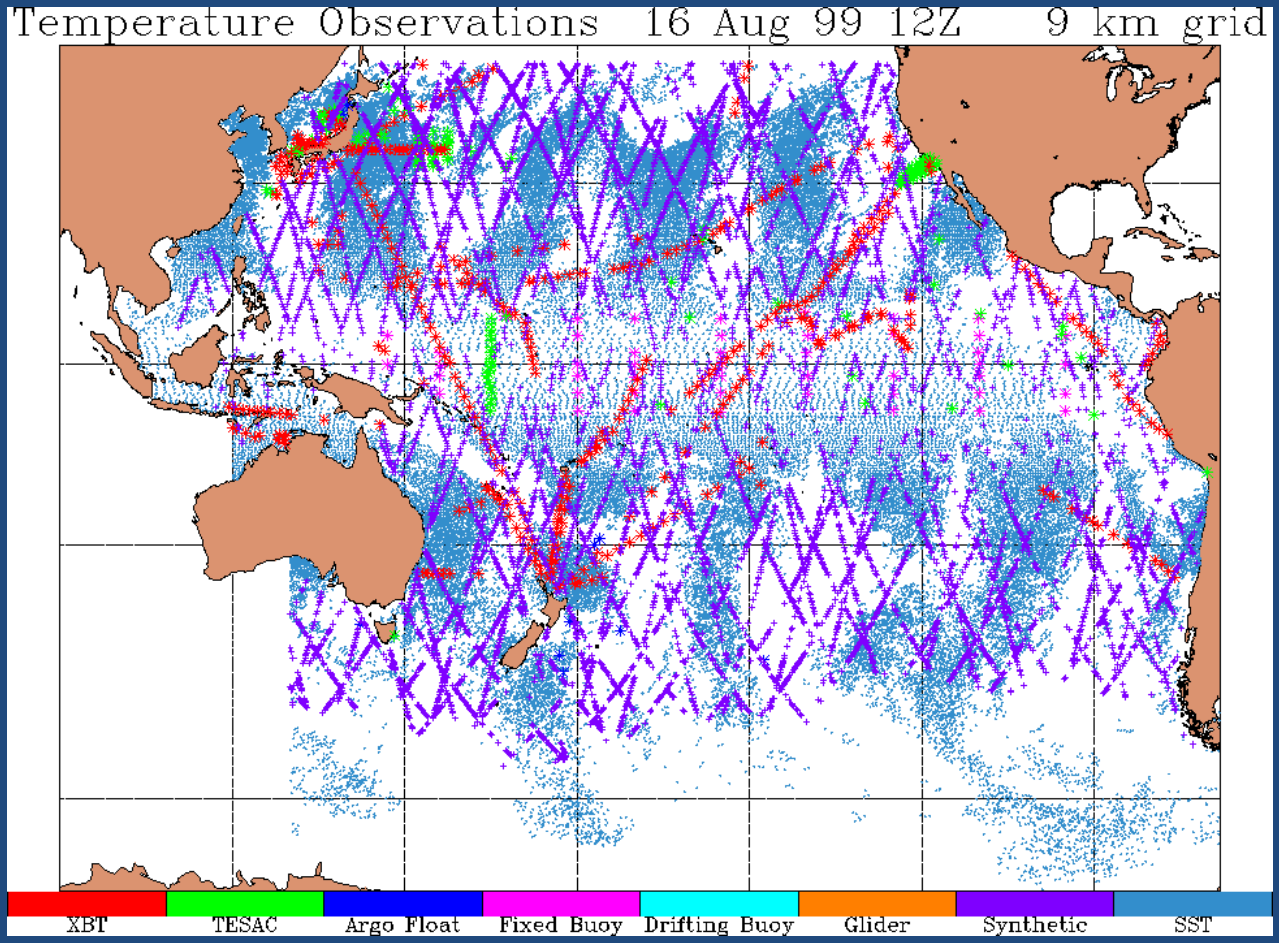


February 19, 2000



Observations to be Assimilated via NCODA

August 16 – September 16 1999

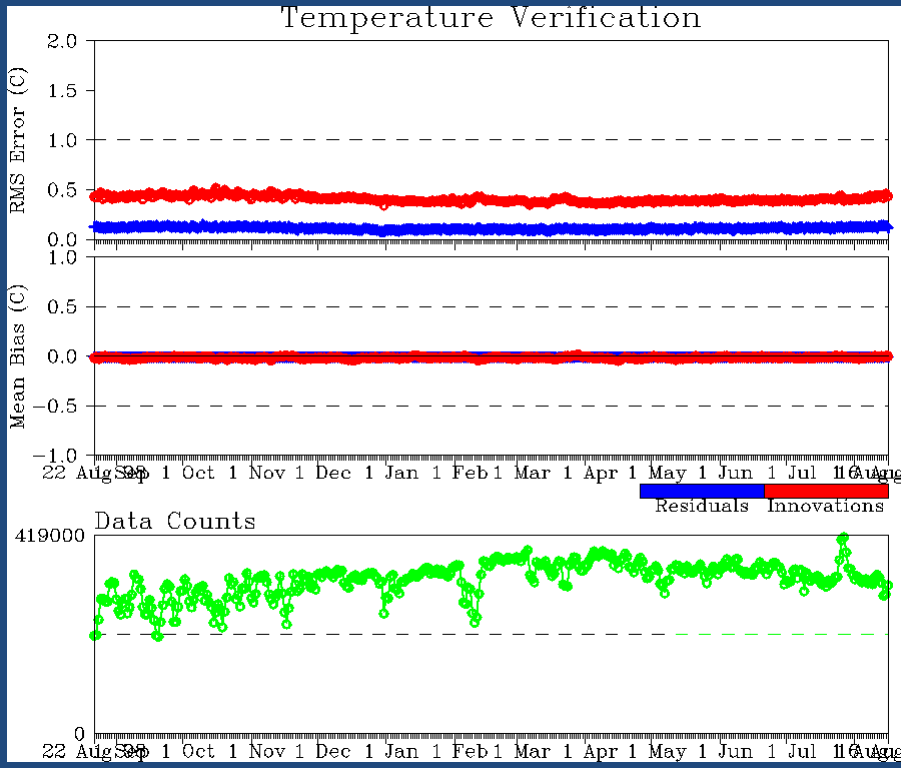


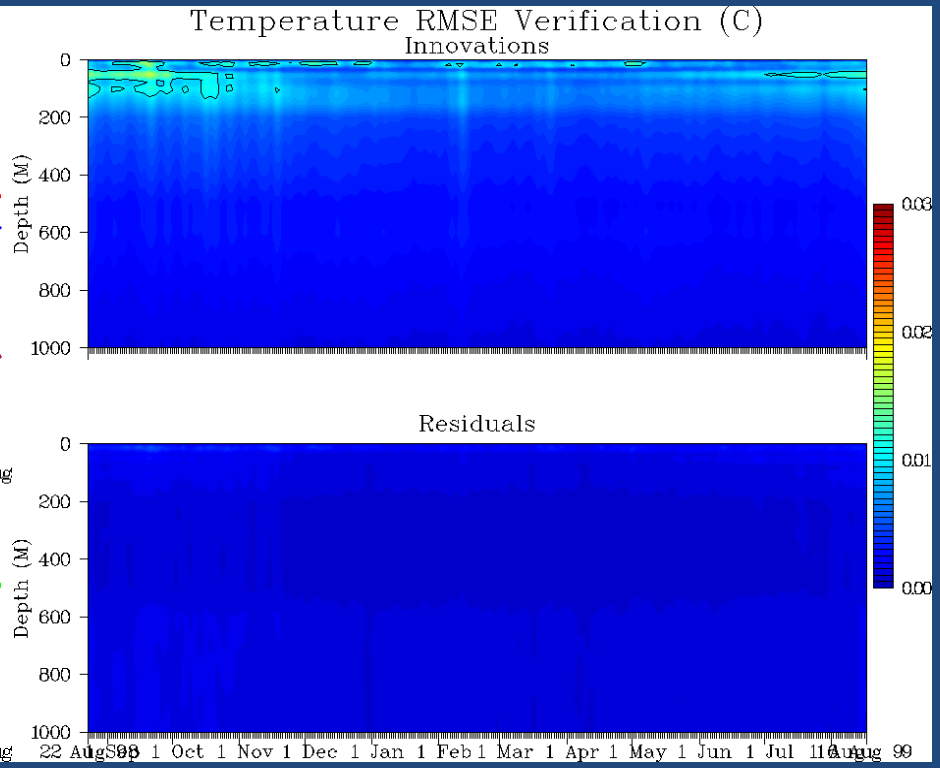
SSH Observations: 3-day data window
SST Observations: 24 hour data window
Profiles: 12-day data window

Modular Ocean Data Assimilation System (MODAS) used as vertical projection of the satellite altimeter observations

Temperature Verification in the Pacific

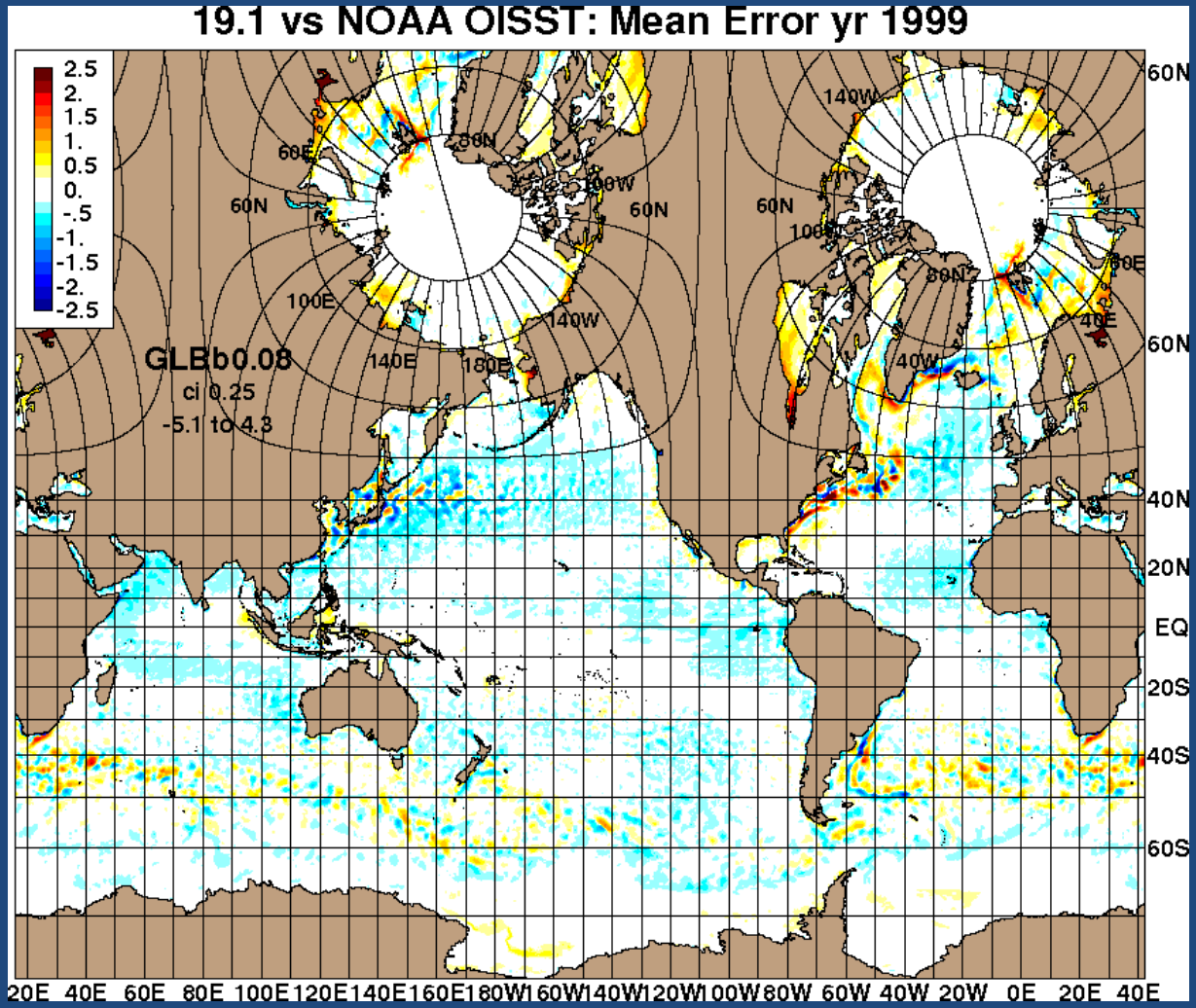
August 1998 to August 1999





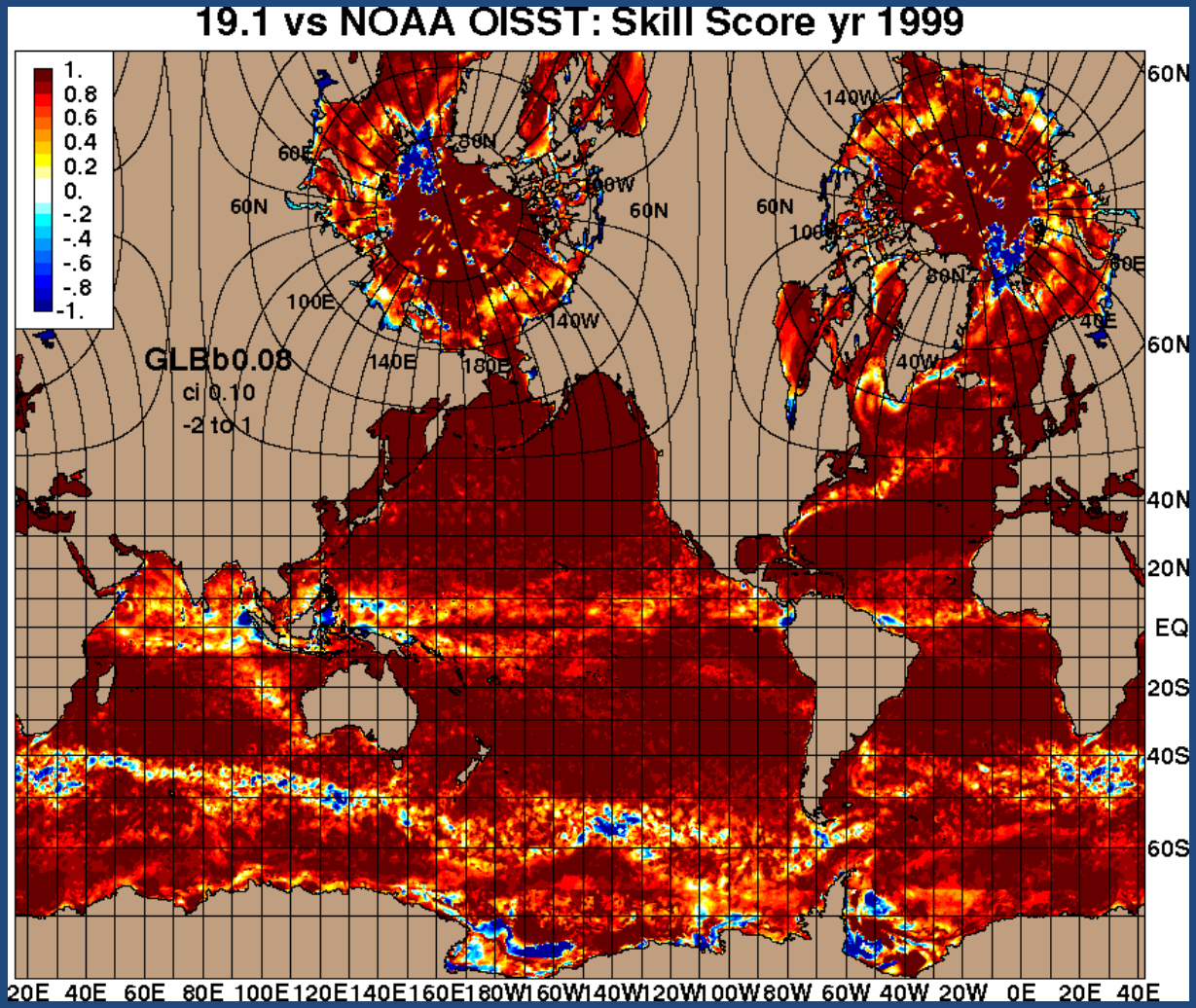
SST Mean Error

1999

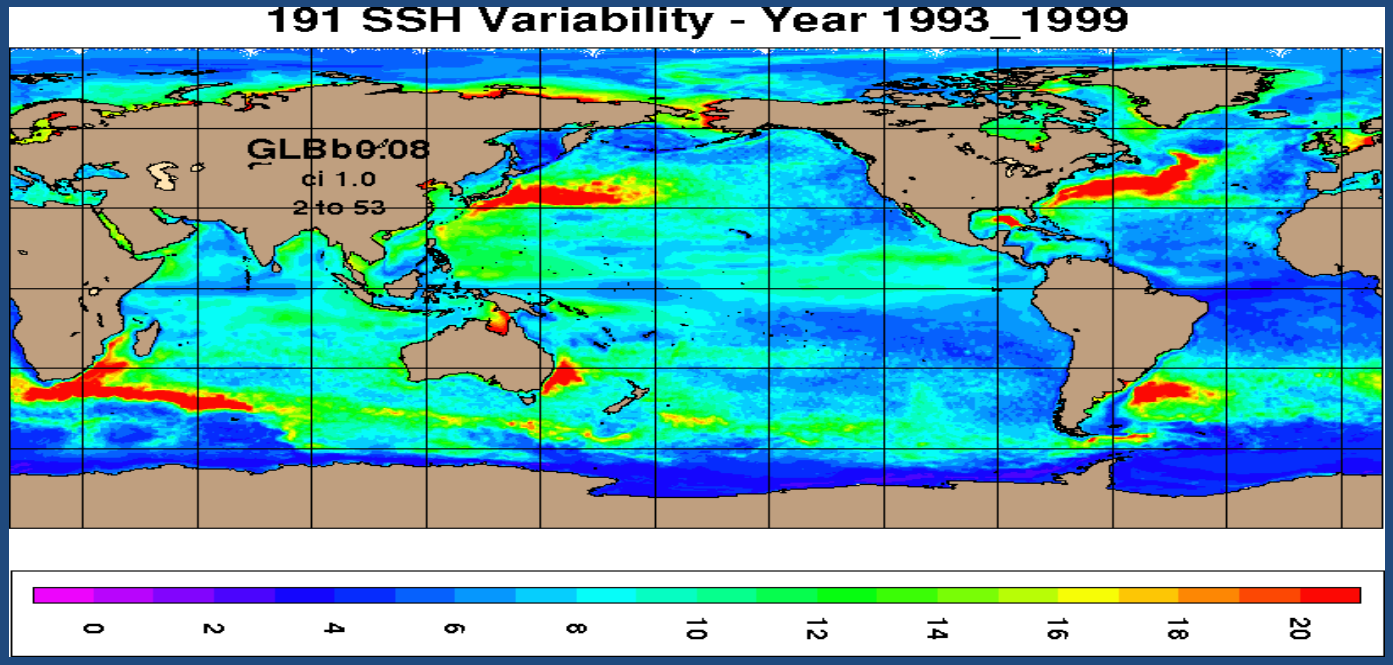


SST Skill Score

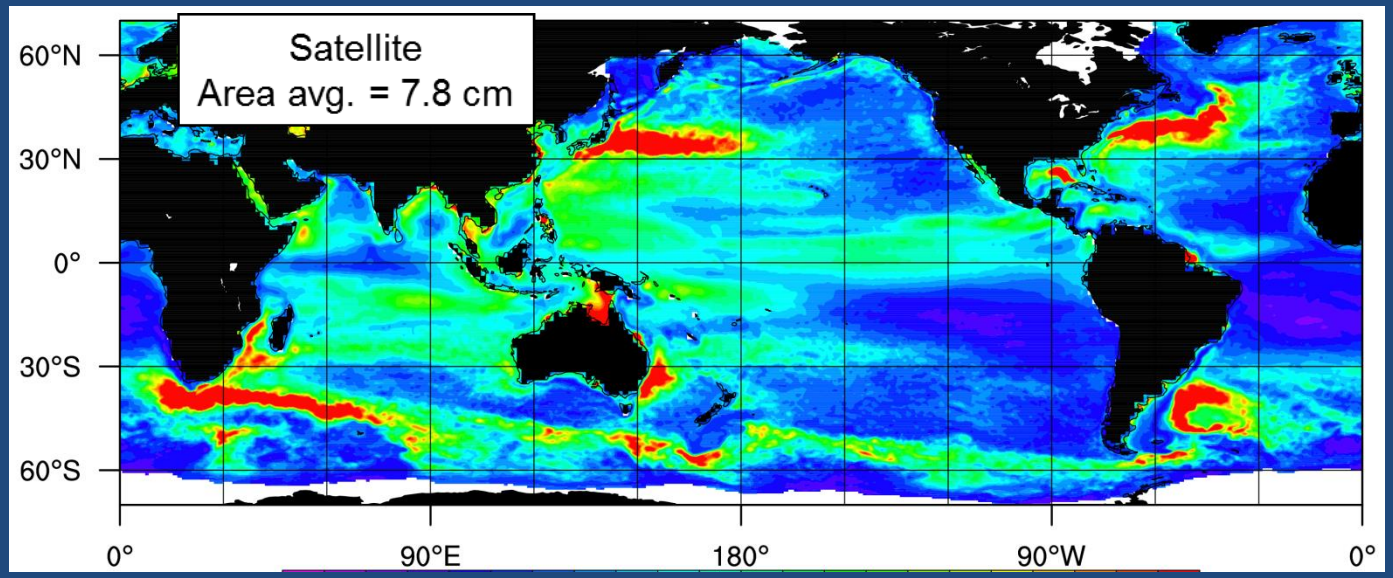
1998



SSH Variability



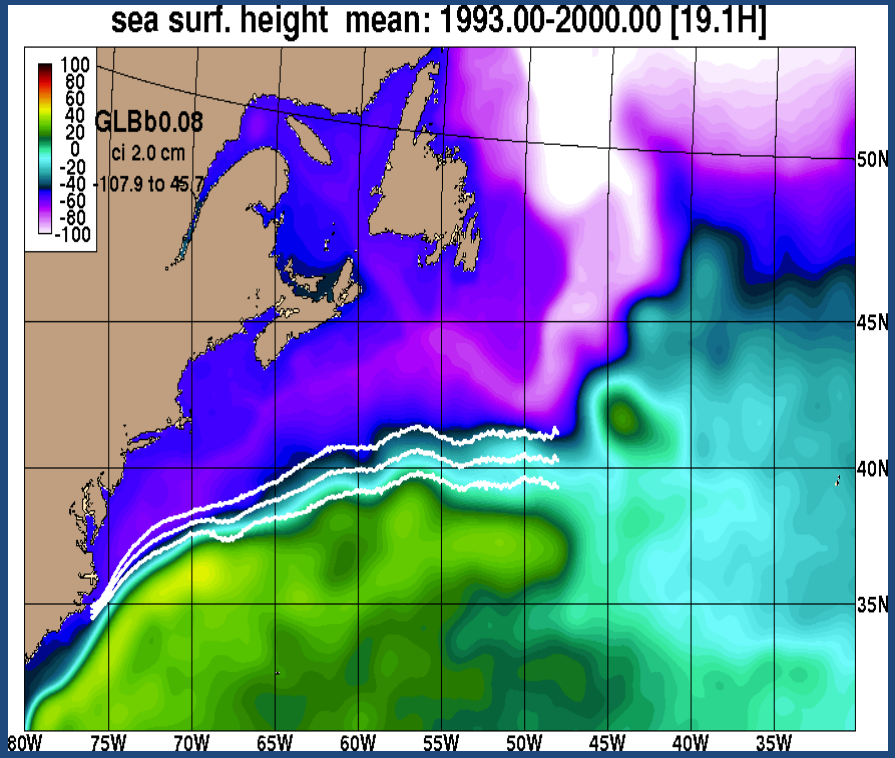
1993-1999



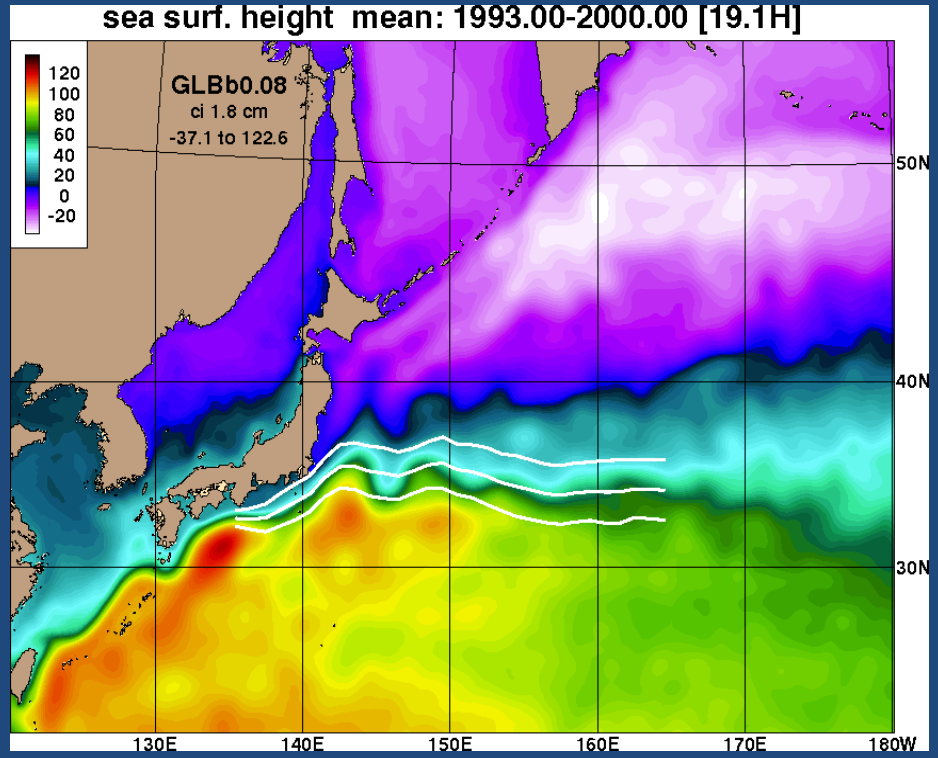
Oct 92 – May 07 SSH variability based on T/P, ERS-1 and ERS-2 altimeters (from Collecte, Localisation, Satellites (CLS))

Mean SSH
1993-1999

Gulf Stream region

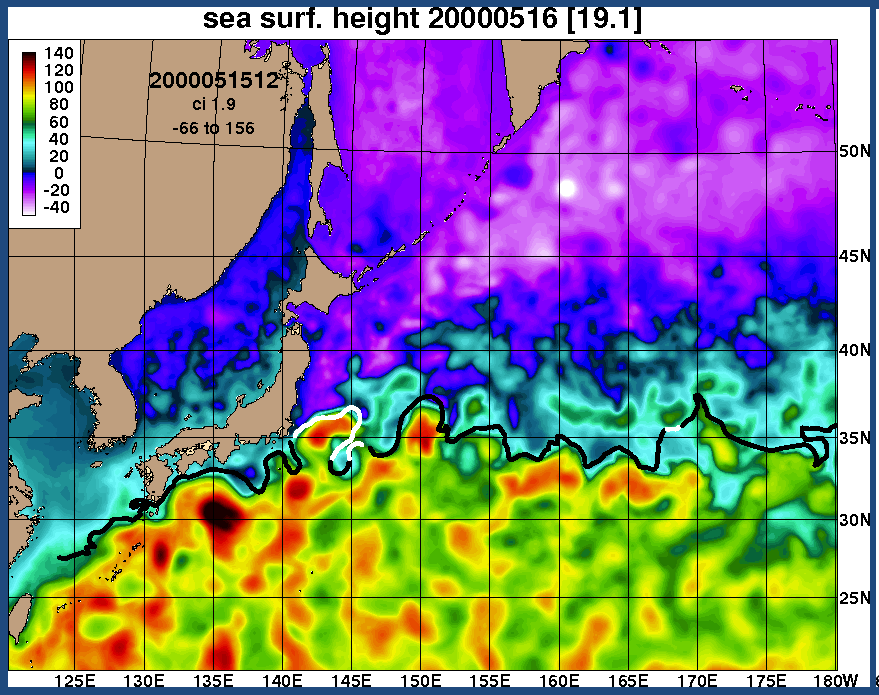


Kuroshio region

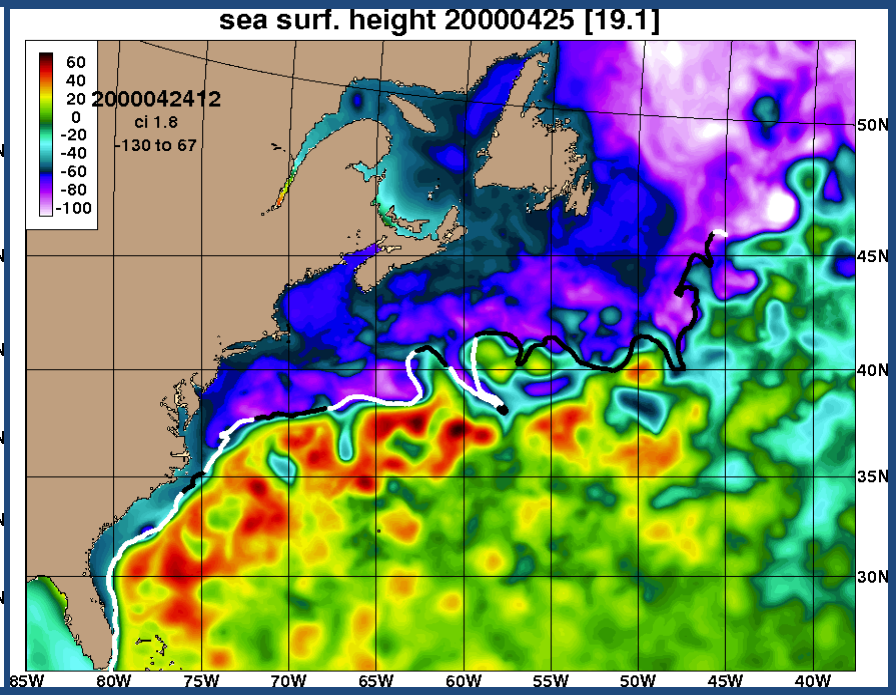


Kuroshio and Gulf Stream SSH with SST-based frontal analysis

SSH May 16 2000



SSH April 25 2000



Frontal analysis < 4 days old = white,

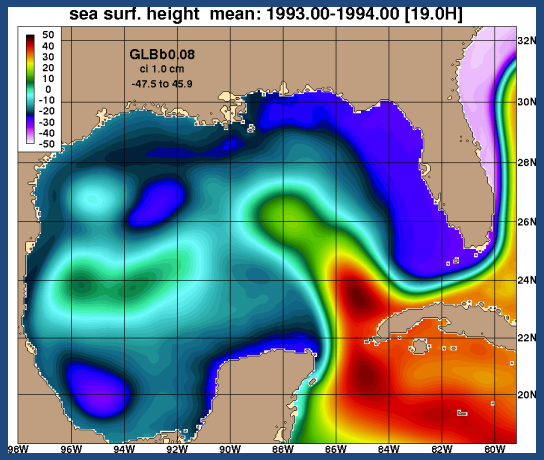
Frontal analysis ≥ 4 days old = black

Frontal analysis performed by the Naval Oceanographic Office

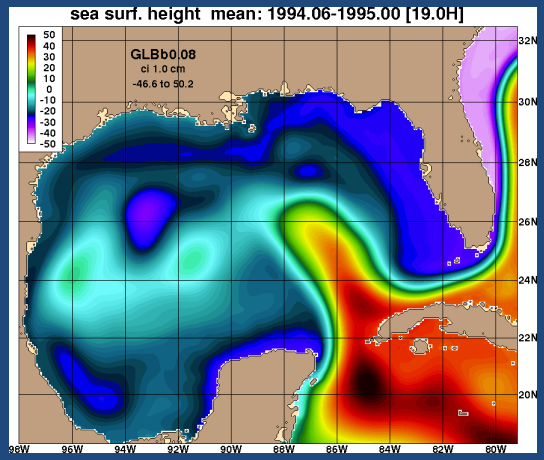
Mean SSH

Gulf of Mexico Region

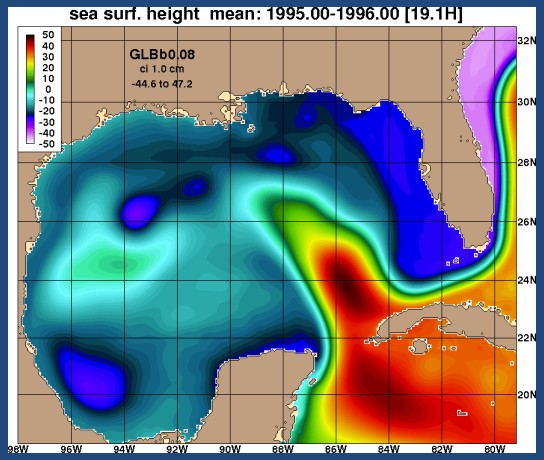
1993



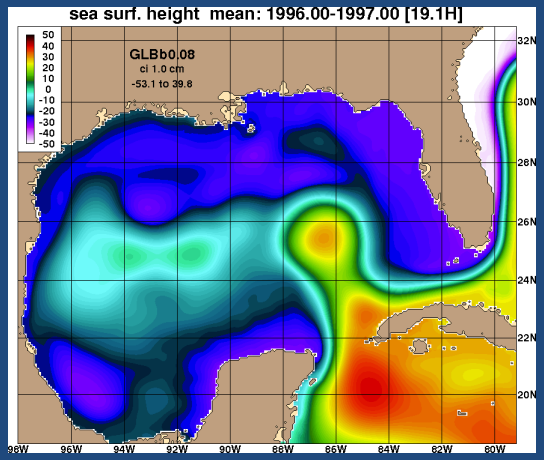
1994



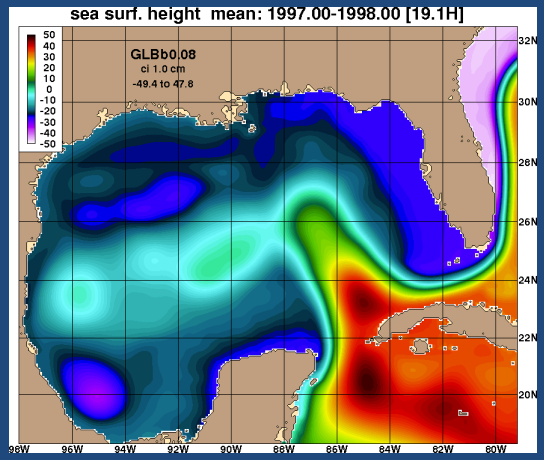
1995



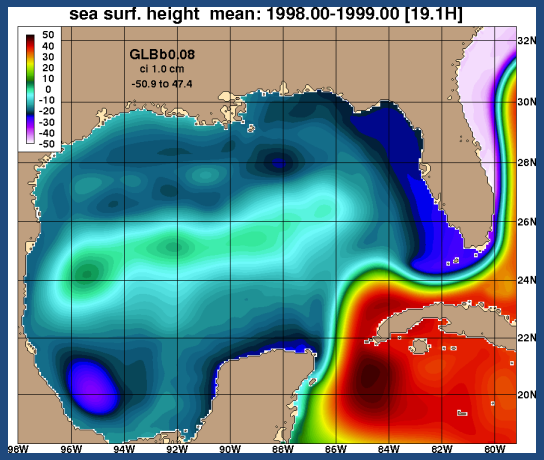
1996



1997

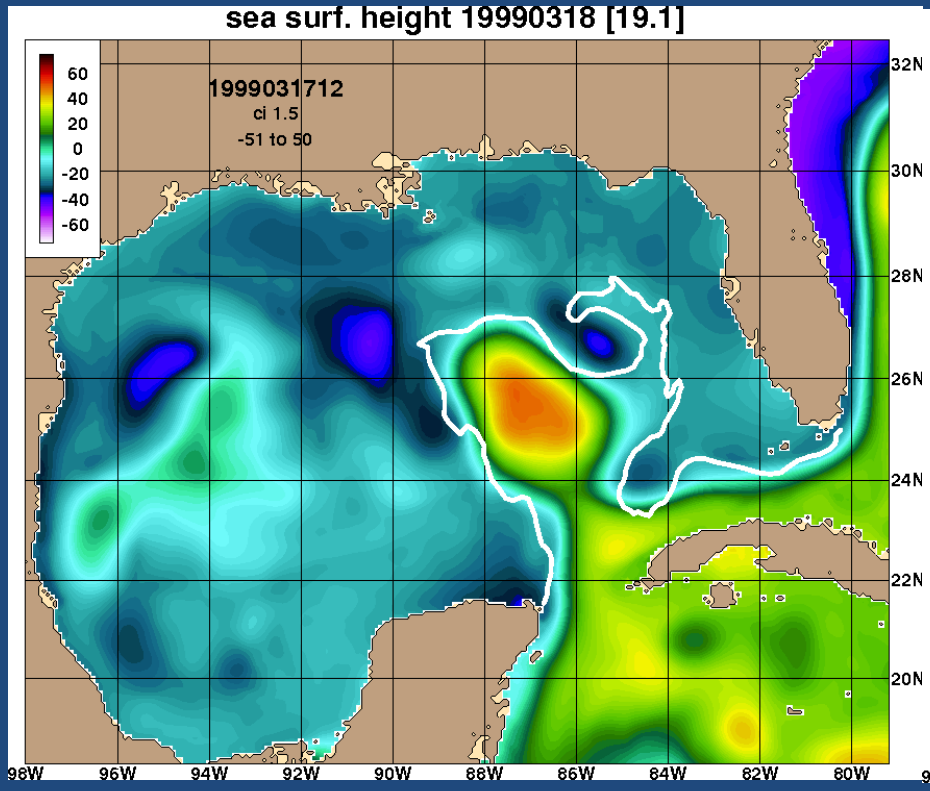


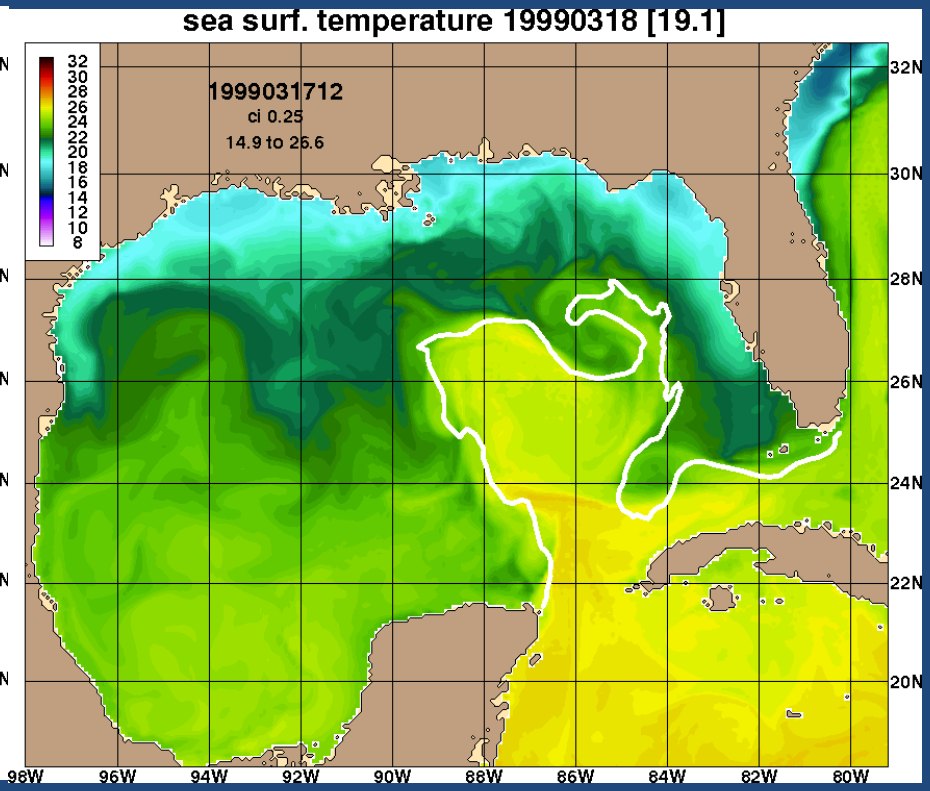
1998



Gulf of Mexico SSH and SST with SST-based frontal analysis

March 3 1999

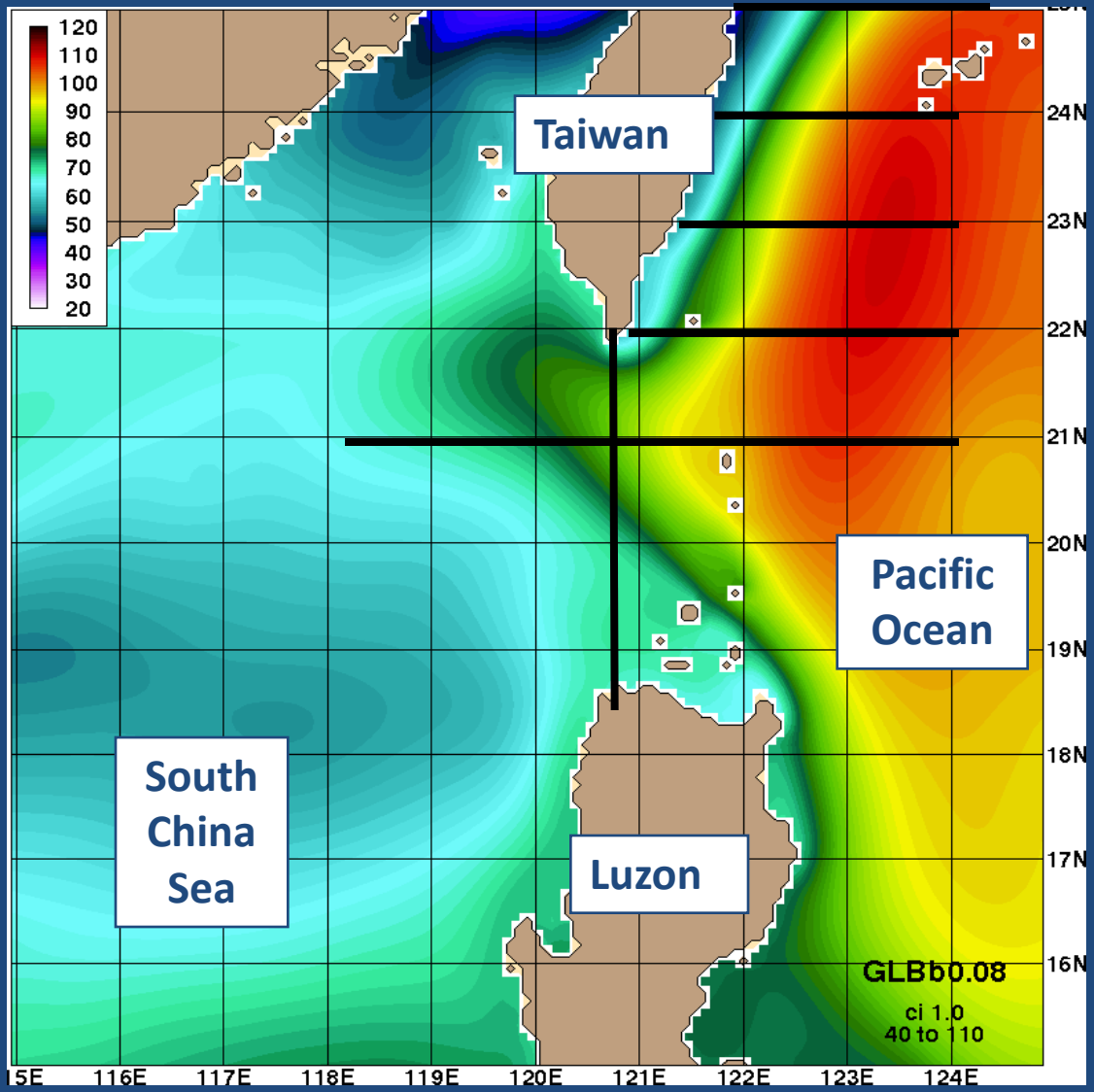




Frontal analysis < 4 days old = white,
analysis ≥ 4 days old = black

Frontal analysis performed by the Naval Oceanographic Office

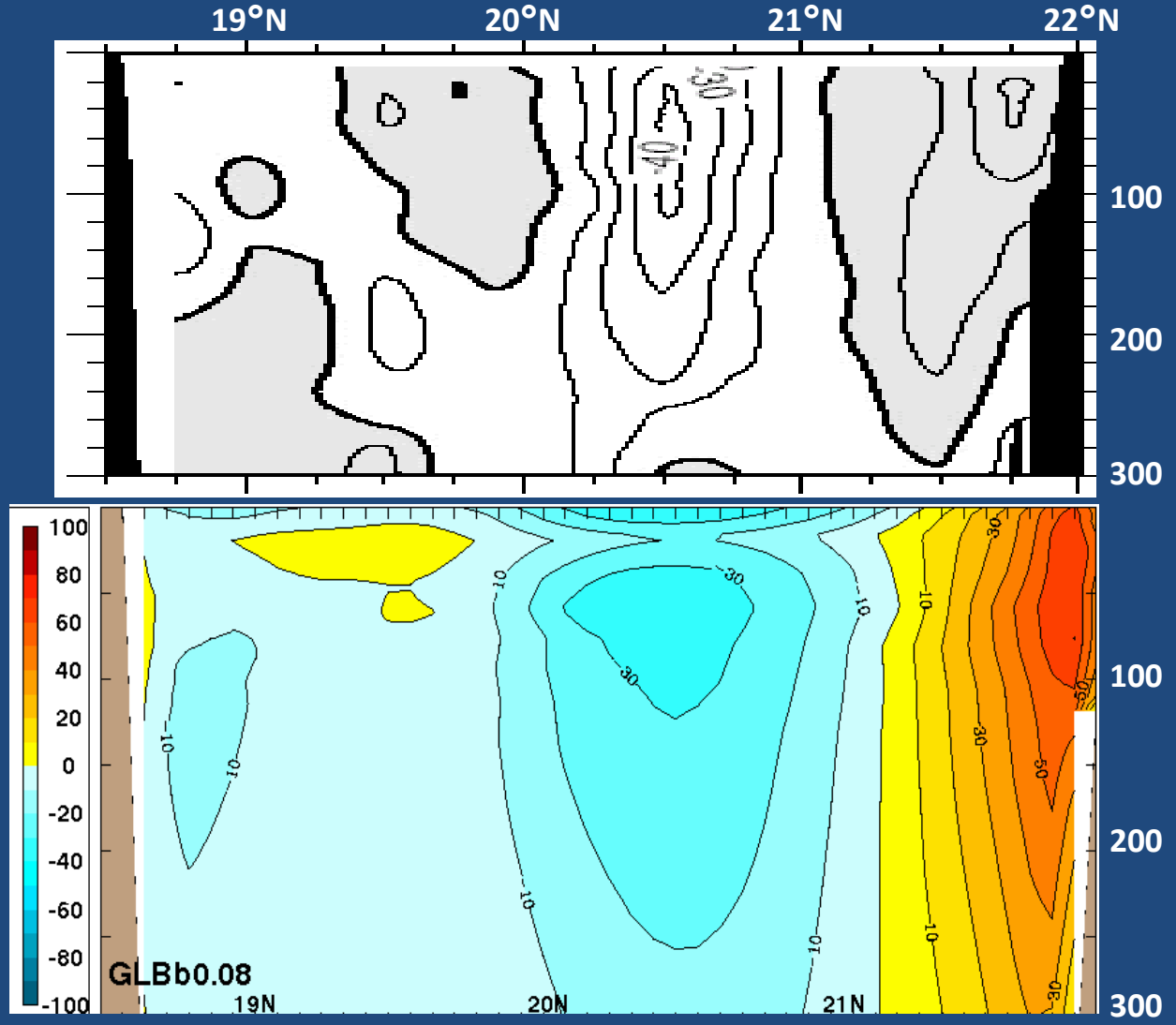
1993-1999 Mean SSH in Luzon Strait



Forced with 1 hourly CFSR winds and thermal forcing

Velocity Cross-section Across Luzon Strait

Sb-ADCP data (top) vs. 1/12° Global HYCOM (bottom) in the upper 300 m
Section along 120.75°E between Taiwan and Luzon



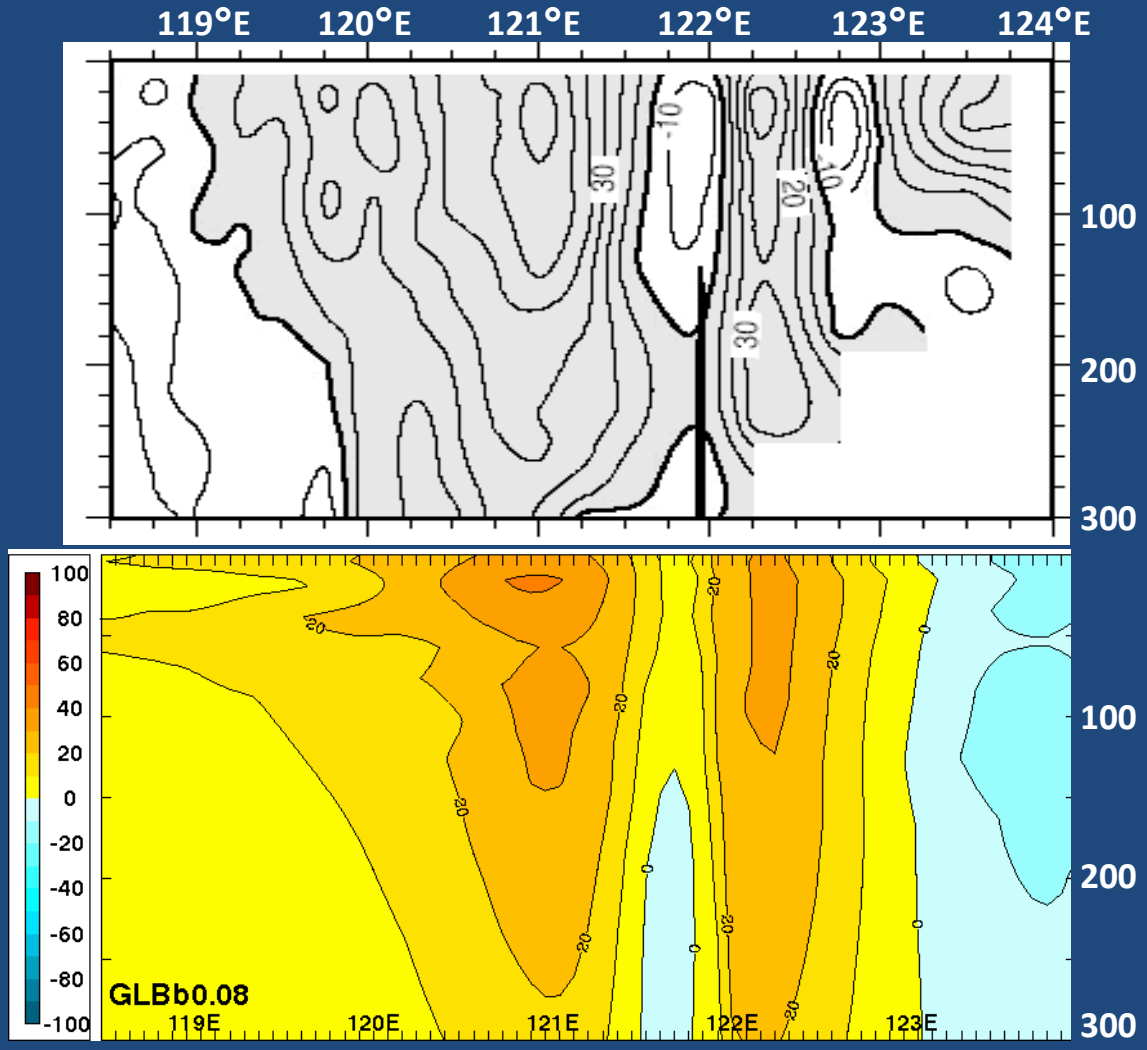
Westward velocity: 40+ cm/s

Westward velocity: 30+ cm/s

Sb-ADCP data from Liang et al. (2003,DSR Pt. II), 1991-2000
1993-1999 mean from HYCOM forced with 1 hourly CFSR winds and thermal forcing

Velocity Cross-section Along Luzon Strait

Sb-ADCP data (top) vs. 1/12° Global HYCOM (bottom) in the upper 300 m
Section along 21°N between 118.5°E and 124.0°E



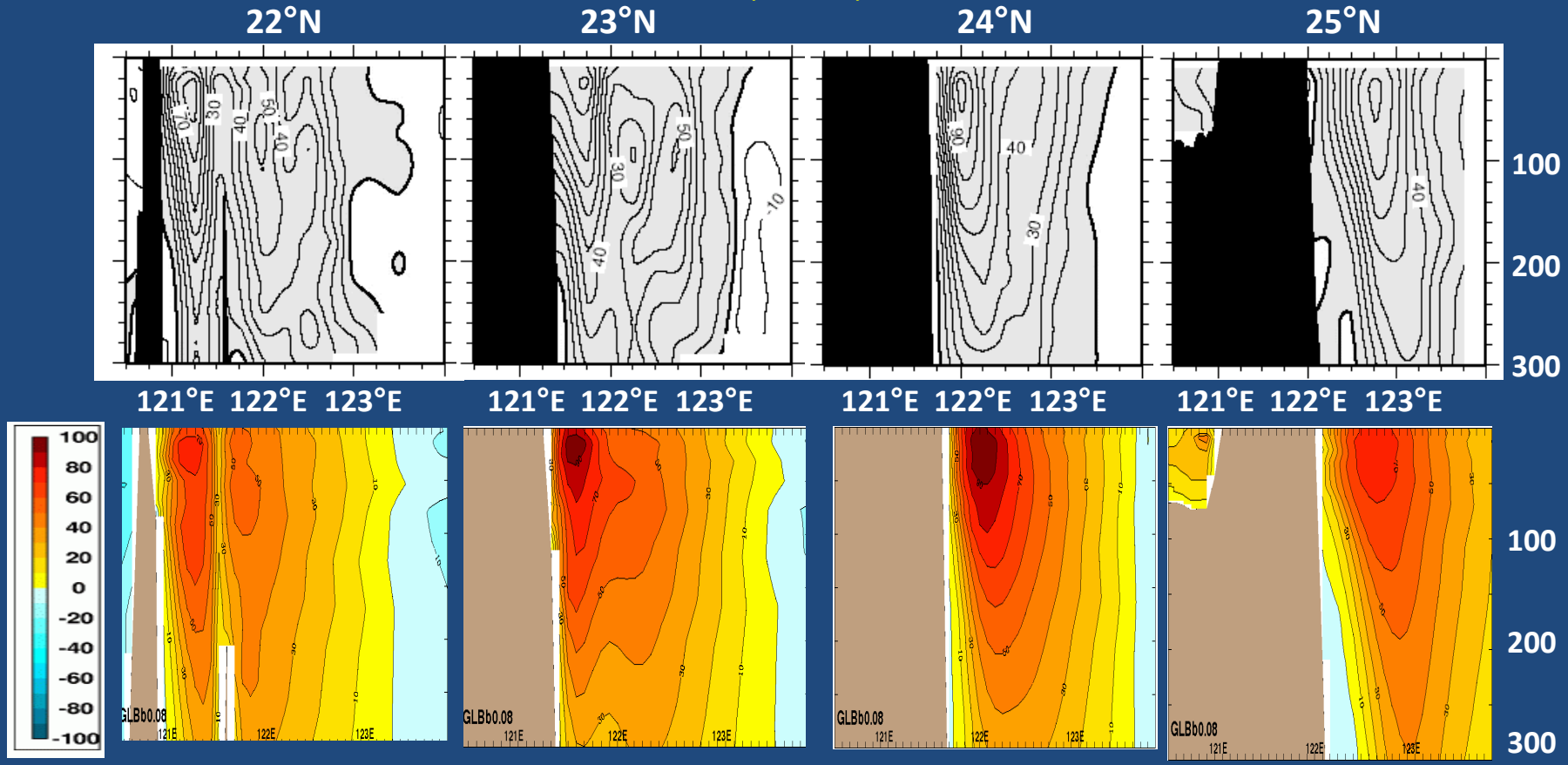
Northward velocity of western core: 60+ cm/s

Northward velocity of western core: 40+ cm/s

Sb-ADCP data from Liang et al. (2003, DSR Pt. II), 1991-2000
1993-1999 mean from HYCOM forced with 1 hourly CFSR winds and thermal forcing

Velocity Cross-sections East of Taiwan

Sb-ADCP data (top) vs. 1/12° Pacific HYCOM (bottom) in the upper 300 m
Sections at 22°N, 23°N, 24°N and 25°N



Sb-ADCP data from Liang et al. (2003, DSR Pt. II)
1993-1999 mean from HYCOM forced with 1 hourly CFSR winds and thermal forcing

Note how the two-core Kuroshio merges to a single jet in both the observations and HYCOM from the south to north along the Taiwan coast

WOCE PCM-1 Transport

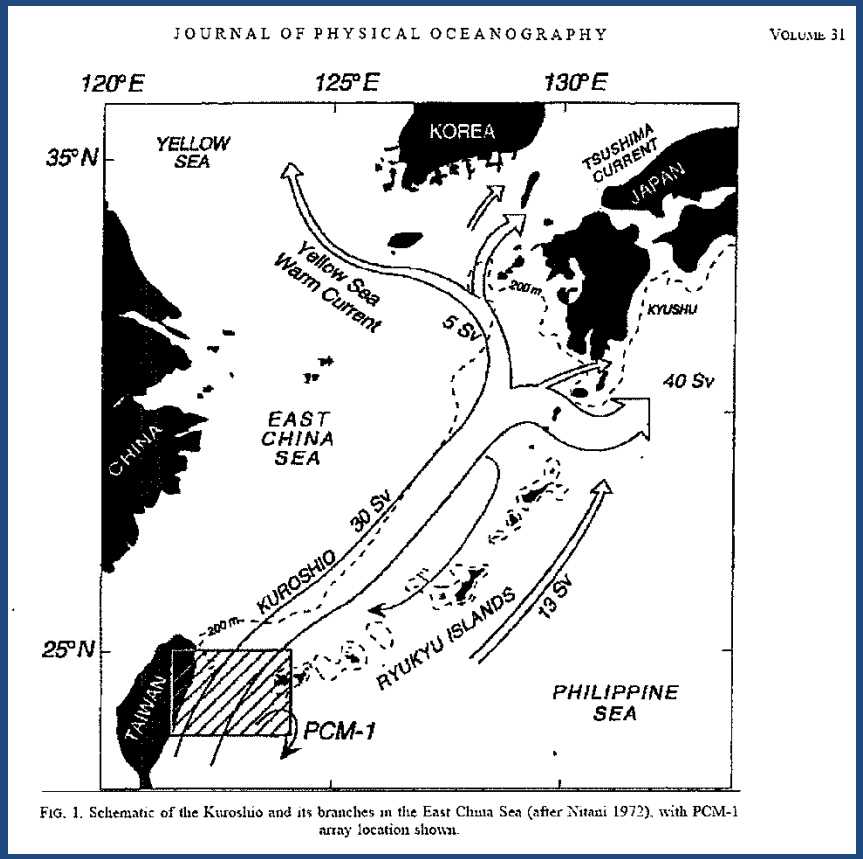


FIG. 1. Schematic of the Kuroshio and its branches in the East China Sea (after Nitani 1972), with PCM-1 array location shown.

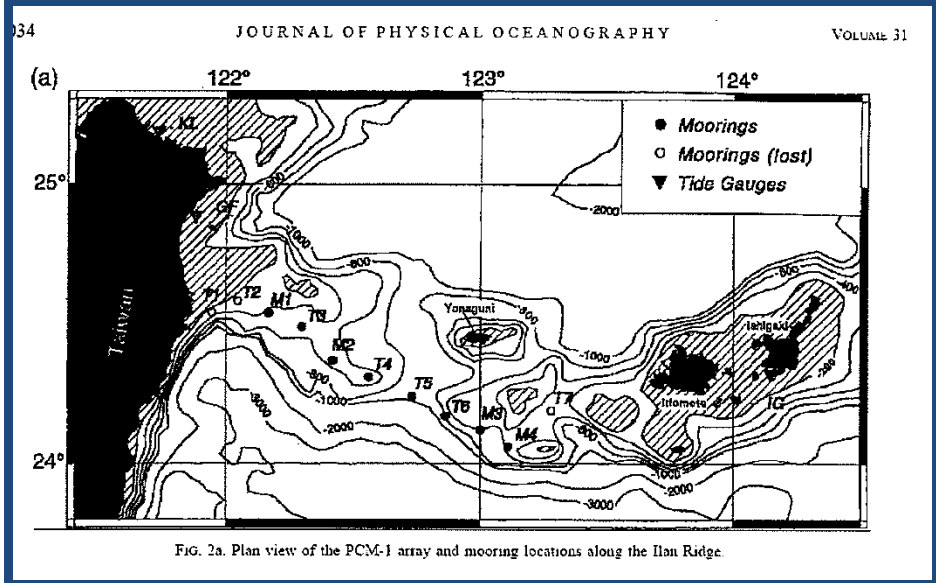
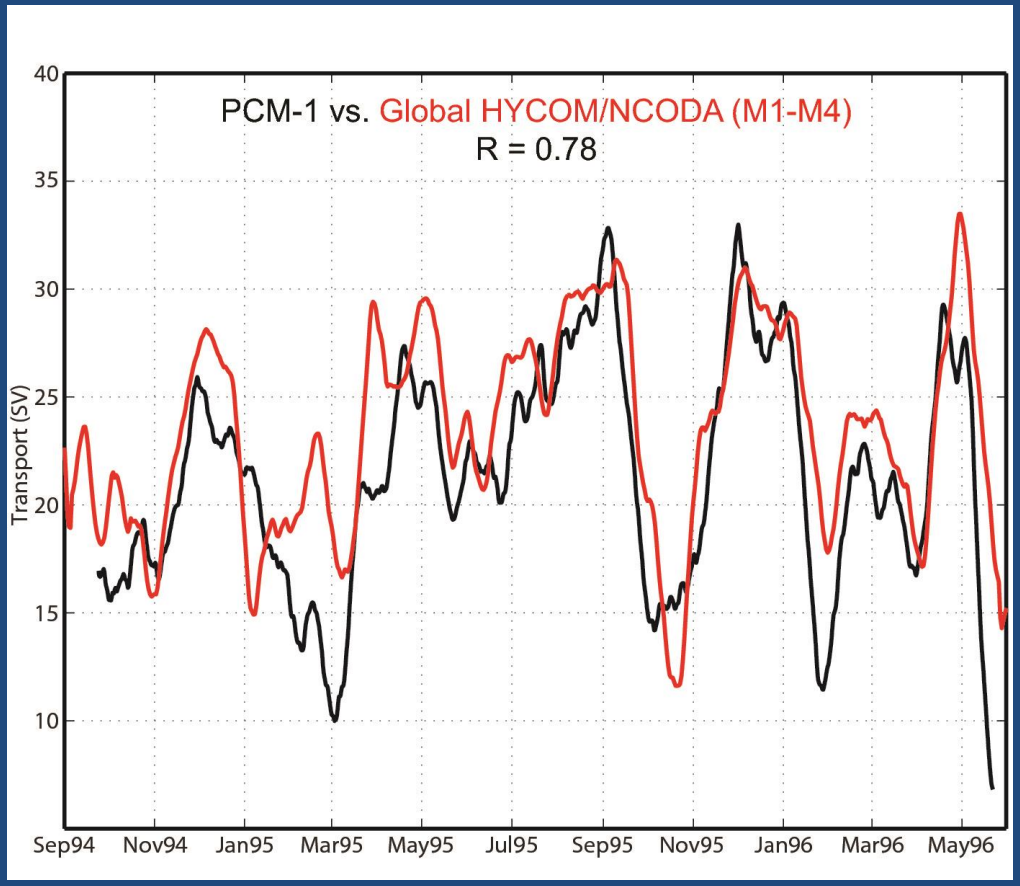


FIG. 2a. Plan view of the PCM-1 array and mooring locations along the Ilan Ridge.

From Johns et al. 2001

WOCE PCM-1 Transport



WOCE PCM-1 transport (black) via the adjusted geostrophic method from Johns et al. (2001) versus full water column transport from the global HYCOM/NCODA Ocean Reanalysis (red) using those model gridpoints between moorings M1 – M4. A ten day filter has been applied to both time series. The unfiltered mean and standard deviation for PCM-1 are 22.0 ± 4.8 Sv while that for global HYCOM is 23.7 ± 9.8 Sv. The correlation coefficient is 0.78.

Computational Requirements

- Computer time via the DoD High Performance Computing Modernization Office
- Currently integrating the ocean reanalysis on the Navy DoD Supercomputing Resource Center (DSRC) IBM iDataPlex
- Using 949 processors
  - Integrate up to 22 model days every 24 hrs of wall time
  - It will take ~8 months to integrate the remainder

Output and Storage

- HYCOM 3D native grid archive files (compressed):
  - Single hour: ~7 Gb
  - Saving 3-hourly output:
    - ~20 Tb / model year
    - ~340 Tb for the entire reanalysis
- HYCOM 3D constant .08° grid (±80° lat) netCDF files remapped to 40 z-levels (compressed):
  - Single hour: ~1.2 Gb
  - Saving 3-hourly output:
    - ~3.5 Tb / model year
    - ~59 Tb for the entire reanalysis
- Subset of the output will be placed on the hycom.org data server
  - When is still to be determined